Nutrition and Ultraendurance: An Overview

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CHAPTER

14

c0014 Nutrition and Ultraendurance: An Overview [AU1]

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s0010 INTRODUCTION

p0010 Ultraendurance performance is defined as an endurance performance lasting for 6h or longer [1]. Ultraendurance athletes compete for hours, days, or even weeks and face different problems regarding nutrition which may occur as a single problem or in combination. The continuous physical stress consumes energy, and an energy deficit occurs. An optimal nutrition might decrease the risk of energy depletion [2]. Furthermore, ultraendurance performances may lead to dehydration due to sweating. An optimal hydration is vital in preventing medical conditions such as heat illness and hyponatremia [3]. Ultraendurance athletes have unique characteristics compared with endurance athletes, e.g., it has been shown that ultramarathoners were more likely to be vegan or vegetarian than half- or full-marathoners [4]; therefore their nutrition should be subjected to special attention.

p0015 We may separate these two problems into (1) energy deficit with corresponding loss in solid body masses such as fat mass and skeletal muscle mass and (2) dysregulation of fluid metabolism with dehydration or fluid overload with the risk of exercise-associated hyponatremia (EAH).

p0020 Before considering potential aspects of nutrition during ultraendurance races, we need to review the existing literature regarding the previously cited problems. The findings may help to give recommendations or prescriptions for nutrition in ultraendurance performances.

s0015 PROBLEMS ASSOCIATED WITH ULTRAENDURANCE PERFORMANCE

s0020 Energy Turnover and Energy Deficit in Ultraendurance

p0025 An ultraendurance athlete competing for hours or days with or without breaks expends energy [5–25]. Meeting the energy demands of ultraendurance athletes requires careful planning and monitoring of food and fluid intake [13,26]. Numerous controlled case reports [5,13,16–22,27] and field studies [7,12,28–31] on ultraendurance performances showed, however, that ultraendurance athletes were unable to self-regulate diet or exercise intensity to prevent a negative energy. For instance, a 54-km mountain ultramarathon resulted in a 3704 kcal negative energy balance [32]. Furthermore, the insufficient energy intake is also associated with malnutrition such as a low intake of antioxidant vitamins [33]. Cyclists in a 1230-km race who had a larger energy deficit showed a more pronounced drop in IGF-1, an index of endocrine changes due to starvation [34].

p0030 Generally an adequate food and fluid intake is related to a successful finish in an ultraendurance race [12,33,35]. An important key to a successful finish in an ultraendurance race seems to be an appropriate nutrition strategy during the race [36]. An energy deficit impairs ultraendurance performance. In ultracyclists a significant negative relationship between energy intake and finish time in a 384-km cycle race has been demonstrated [31]. An ultraendurance performance leads to an energy deficit [5,7–19,22,24–27,37–44]. In Table 14.1, results from literature are summarized and separated by discipline (i.e., swimming, cycling, running, and the combination as triathlon). Regarding the single disciplines, the energy deficit seems higher in swimming than in cycling and running. This might be explained by

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t0010 **TABLE 14.1** Energy Balance in Ultraendurance Athletes in Swimming, Cycling, Running, and Triathlon

Distance and/or Time	Subjects	Total Energy Intake (kcal)	Total Energy Expenditure (kcal)	Total Energy Deficit (kcal)	Energy Deficit in 24 h (kcal)	Energy Deficit per hour (kcal)	References
SWIMMING							
26.6 km	1 male	2105	5540	−3435	–	−429	[18]
26.6 km	1 male	–	–	–	–	−500	[37]
24-h swim	1 male	3900	11,460	−7480	−7480	−311	[38]
Mean ± SD						−413 ± 95	
CYCLING							
12-h indoor cycling	1 male	2750	5400	−2647	–	−220	[22]
557 km in 24 h	1 male	5571	15,533	−9915	−9915	−413	[27]
617 km in 24 h	1 male	10,000	13,800	−3800	−3800	−158	[16]
694 km in 24 h	1 male	10,576	19,748	−9172	−9172	−382	[13]
24 h cycling	6 males	8450	18,000	−9590	−9590	−399	[14]
1000 km in 48 h	1 male	12,120	16,772	−4650	−2325	−96	[24]
1126 km in 48 h	1 male	11,098	14,486	−3290	−1645	−65	[37]
2272 km in 5 d 7 h	1 male	51,246	80,800	−29,554	−5585	−232	[5]
4701 km in 9 d 16 h	1 male	96,124	179,650	−83,526	−8352	−360	[10]
Mean ± SD					−6298 ± 3392	−258 ± 134	
RUNNING							
160 km in 20 h	1 male	9600	8480	−1120	–	−56	[40]
320 km in 54 h	1 male	14,760	18,120	−3360	−1493	−62	[11]
501 km in 6 days	1 male	39,666	54,078	−14,412	−2402	−100	[9]
Atacama crossing	1 male	37,191	101,157	−63,966	−3046	−127	[25]
100 km	11 female	570	6310	−5750	–	−452	[41]
100 km	27 male	760	7420	−6660	–	−580	[42]
Mean ± SD					−2313 ± 780	−229 ± 227	
TRIATHLON							
Triple iron ultratriathlon	1 male	15,750	27,485	−11,735	−6869	−286	[43]
Triple iron ultratriathlon	1 male	22,500	28,600	−6100	−3404	−141	[19]
Gigathlon multistage triathlon	1 male	38,676	59,622	20,646	−9937	−414	[17]
10 × Ironman triathlon	1 male	77,640	89,112	−11,480	−7544	−314	[44]
Mean ± SD					−6938 ± 2,699	−288 ± 112	

SD, stanadrd deviation.

the different environment (water) compared with cycling and running. For events lasting 24 h or longer, the energy deficit is highest in multisports disciplines and cycling. In running, the energy deficit is around three times lower than in both triathlon and cycling.

s0025 Change in Body Mass During an Ultraendurance Performance

p0035 An ultraendurance performance leads to a loss in body mass (Table 14.2) [5,9–11,13,15,16,19,21,23–25,37,38,41,43–56], which can be >5% in a few cases (Garth, 2013). [AU3] For instance, the participation in a 24-h ultramarathon (distance covered: 122–208 km) resulted in body mass decreased by 1.7% [57], whereas a ~230-km ultramarathon induced a body mass decreased by 1.0%–2.5% [58]. Participants in an 800-km Antarctic race (14–28 days) had their body mass and lean mass decreased by 8.3 kg and 2.0 kg, respectively [59]. The loss in body mass occurs preferably in the lower trunk [9,25,48]. Depending on the length of an endurance performance and the discipline, the decrease in body mass corresponds to a decrease in fat mass [5,11,14,21,22,44,45,51–55] and/or skeletal muscle mass [5,11,20,44–47,49,50,54]. [AU4] It seems that a concentric performance such as cycling rather leads to a decrease in fat mass [22,53], whereas an eccentric performance such as running rather leads to a decrease in muscle mass [47]. In runners a decrease in both fat mass and skeletal muscle mass has been observed [46,47]. For swimmers, no change in body mass, fat mass, or skeletal muscle mass has been reported in 12-h indoor pool swimmers [60]. In male open-water ultraswimmers, however, a decrease in skeletal muscle mass was observed [61].

p0040 In some instances, an increase in body mass has been reported during ultraendurance performances [16,19,21,24,48] (Table 14.2) where an increase in skeletal muscle mass was also found [16,19,21,22,24,43,48] (Table 14.2). The increase in body mass was most probably due to fluid overload, which will be discussed in the next section. An increase in skeletal muscle mass might occur in cases where anthropometric methods were used and an increase in skinfold thicknesses and limb circumferences might occur. This will also be discussed in the next section. Overall, ultraendurance athletes seem to lose ~0.5 kg in body mass and ~1.4 kg in fat mass where skeletal muscle mass seems to remain unchanged. However, total body water seems to increase by ~1.5 L [21,23,24,41,43–46] (Table 14.2).

s0030 Dehydration, Fluid Intake, and Fluid Overload

p0045 Most endurance athletes are concerned with dehydration during an ultraendurance performance. It has been shown that body mass was reduced in a 24-h ultramarathon [62]. However, body mass reduction in ultraendurance athletes seems rather to be due to a decrease in sold mass and not due to dehydration [50,52,63].

p0050 Dehydration refers both to hypohydration (i.e., dehydration induced before exercise) and exercise-induced dehydration (i.e., dehydration that develops during exercise). The latter reduces aerobic endurance performance and results in increased body temperature, heart rate, perceived exertion, and possibly increased reliance on carbohydrate as a fuel source [64]. Fluid replacement is considered to prevent from dehydration, and hypohydration has been shown to impair endurance performance [65]. Adequate fluid intake helps to prevent loss in body mass [29,66]. However, fluid overload may lead to an increase in body mass and a decrease in plasma sodium [67] with the risk to develop EAH [67–69].

p0055 Fluid overload may lead to a considerable increase in body mass [67]. For example, one athlete competing in a Deca Iron ultratriathlon covering 38 km by swimming, 1800 km by cycling, and 422 km by running within 12 d 20 h showed an increase in body mass of 8 kg within the first 3 days [48]. In athletes with a postrace increase in body mass an increase in skinfold thicknesses and limb circumferences of the lower limb has been recorded [24,48]. In another athlete with an increase in body mass an increase in skinfold thicknesses at four skinfold sites has been shown [16]. Both these races were held in rather hot environments where most probably fluid intake was rather high. However, also in athletes with a decrease in body mass, an increase in skinfold thicknesses at the lower limb has been reported [5,44,55]. In one athlete with a decrease in body mass after a Triple Iron ultratriathlon a considerable swelling of the feet was described [43].

p0060 Most probably the increase in body mass, skinfold thicknesses, and limb circumferences was due to an increase in body water [24,44,70] (Table 14.2). In several studies an increase in total body water in ultraendurance athletes has been reported [21,23,24,41,43–47,71,72]. One might now argue about the potential reasons for the increase in both the skinfold thicknesses and total body water. The increase in total body water might be due to an increase in plasma volume [23,71–74], which might be due to sodium retention [71,73] due to an increase activity of aldosterone [23,75]. An association between an increase in plasma volume and an increase in the potassium-to-sodium ratio in urine might suggest that an increased activity of aldosterone [76] may lead to retention in both sodium and fluid during an ultraendurance performance [42]. In a multistage race for more than 7 days, total mean plasma sodium content increased and was the major factor in the increase in plasma volume [71].

p0065 Apart from these pathophysiological aspects, fluid overload might also lead to an increase in limb volume. A recent study showed an association between changes in limb volumes and fluid intake [77]. Because neither renal function nor fluid-regulating hormones were associated with the changes in limb volumes, fluid overload is the most likely reason for increase in both body mass and limb volumes. An actual study showed an association between an increased fluid intake and swelling of the feet in ultramarathoners [78].

s0035 Fluid Overload and Exercise-Associated Hyponatremia

p0070 Fluid overload might lead to EAH, defined as a serum sodium concentration ([Na^+]) <135 mmol/L during or within 24 h of exercise [79]. EAH was first described in the scientific literature in 1985 by Noakes et al. [80] in ultramarathoners in South Africa as being due to "water intoxication."

p0075 Three main factors are responsible for the occurrence of EAH in endurance athletes: (1) overdrinking because of biological or psychological factors; (2) inappropriate secretion of the antidiuretic hormone (ADH), in particular, the

t0015 **TABLE 14.2** Change in Body Composition in Ultraendurance Athletes Competing in Swimming, Cycling, Running, and Triathlon

Distance and/or Time	Subjects	Change in Body Mass (kg)	Change in Fat Mass (kg)	Change in Muscle Mass (kg)	Change in Body Water (L)	References
SWIMMING						
24-h swim	1 male	−1.6	−2.4	−1.5	−3.9	[38]
12-h swim	1 male	−1.1	–	−1.1	–	[37]
CYCLING						
12-h indoor cycling	1 male	−0.4	−0.9	+0.2	–	[22]
617 km in 24 h	1 male	+4.0	+0.9	+2.9	–	[16]
1000 km within 48 h	1 male	+2.5	−1	+0.4	+1.8	[24]
2272 km in 5 d 7 h	1 male	−2.0	−0.79	−1.21	–	[5]
4701 km in 9 d 16 h	1 male	−5	–	–	–	[10]
RUNNING						
12-h run	1 male	+1.5	−4.4	+1.0	+4.9	[21]
320 km in 54 h	1 male	−0.4	−0.3	−1.0	–	[11]
501 km in 6 days	1 male	−3.0	−6.8	–	–	[9]
100 km in 762 min	11 females	−1.5	–	–	+2.2	[41]
100 km in 11 h 49 min	39 males	−1.6	−0.4	−0.7	+0.8	[45]
338 km in 5 days	21 males	–	–	−0.6	–	[47]
1200 km in 17 days	10 males	–	−3.9	−2.0	+2.3	[46]
TRIATHLON						
Triple Iron ultratriathlon	1 male	−1.1	−0.4	+1.4	+2.0	[43]
Triple Iron ultratriathlon	1 male	+2.1	+0.4	+4.4	–	[19]
Deca Iron ultratriathlon	1 male	+3.2	+2.4	+2.4	–	[48]
Quintuple Iron ultratriathlon	1 male	−0.3	−1.9	–	+1.5	[23]
10 × Ironman triathlon	1 male	−1.0	−0.8	−0.9	+2.8	[44]
Ironman triathlon	27 males	−1.8	–	−1.0	–	[49]
Triple Iron ultratriathlon	31 males	−1.7	−0.6	−1.0	–	[50]
10 × Ironman triathlon	8 males	–	−3	–	–	[51]
Mean ± SD		−0.45 ± 2.5	−1.41 ± 2.31	+ 0.08 ± 1.94	+ 1.51 ± 1.30	

SD, stanadrd deviation.

failure to suppress ADH secretion in the face of an increase in total body water; and (3) a failure to mobilize Na^+ from the osmotically inactive sodium stores or alternatively inappropriate osmotic inactivation of circulating Na^+ [79]. Because the mechanisms causing factors (1) and (3) are unknown, it follows that the prevention of EAH requires that athletes be encouraged to avoid overdrinking during exercise.

p0080 EAH is the most common medical complication of ultradistance exercise and is usually caused by excessive intake of hypotonic fluids [81,82]. The main reason for developing EAH is the behavior of overdrinking during an endurance performance by excessive fluid consumption [68] and/or inadequate sodium intake [83]. Subjects suffering EAH during an ultraendurance performance consumed the double of fluids compared with subjects without EAH [68]. Generally, fluid overload is reported for slower athletes [84]. However, in ultraendurance athletes, faster athletes drink more than slower athletes but seem not to develop EAH [85,86].

p0085 The environmental conditions seem to influence the prevalence of EAH. Often EAH is a common finding in ultraendurance races held in extreme cold [83,87] or extreme heat climates [67,88]. In temperate climates, EAH is relatively uncommon [75,89–102]. There seems to be a gender difference where females seem to be at higher risk to develop EAH [87]. Compared with marathoners [84,103–105], the prevalence of EAH in ultramarathoners is, however, not high [93,102,106].

p0090 The prevalence of EAH seems also to be dependent on the discipline (Table 14.3). EAH was highly prevalent in ultraswimming [87] and ultrarunning [88], whereas the prevalence of EAH was low [91,107] or even absent [90,92]

t0020 **TABLE 14.3** Prevalence of EAH in Ultraendurance Athletes Competing in Swimming, Cycling, Running, and Multisports Disciplines

Distance and/or Time	Conditions	Subjects	Prevalence of EAH	References
SWIMMING				
26-km open-water ultraswim	Moderate	25 males and 11 females	8% in males and 36% in females	[87]
CYCLING				
665-km mountain bike race	Moderate	25 cyclists	0%	[90]
109-km cycle race	Moderate	196 cyclists	0.5%	[91]
720-km ultracycling race	Moderate	65 males	0%	[92]
RUNNING				
161-km mountain trail run	Hot	45 runners	51%	[67]
161-km mountain trail run	Hot	47 runners	30%	[88]
60-km mountain run	Moderate	123 runners	4%	[93]
100-km ultramarathon	Moderate	50 male runners	0%	[75]
100-km ultramarathon	Moderate	145 male runners	4.8%	[86]
24-h ultrarun	Moderate	15 males	0%	[94]
90-km ultramarathon	Moderate	626 runners	0.3%	[80]
160-km trail race	Hot	13 runners	0%	[29]
MULTIDISCIPLINES				
100-mile Iditasport ultramarathon	Cold	8 cyclists and 8 runners	44%	[83]
161-km race	Cold	20 athletes	0%	[95]
Kayak, cycling, and running	Moderate	48 triathletes	2%	[96]
Ironman triathlon	Moderate	330 triathletes	1.8%	[97]
Ironman triathlon	Moderate	330 triathletes	18%	[98]
Ironman triathlon	Moderate	95 triathletes	9%	[99]
Ironman triathlon	Moderate	18 triathletes	28%	[100]
Triple Iron ultratriathlon	Moderate	31 triathletes	26%	[101]

EAH, exercise-associated hyponatremia.

in ultracycling. An explanation could be that cyclists can individually drink by using their drink bottles on the bicycle. In addition, the length of an ultraendurance race seems to increase the risk for EAH. The highest prevalence of EAH has been found in Ironman triathlons [98,100], Triple Iron ultratriathlons [101], and ultramarathons covering 161 km [67,88].

s0040

NUTRITIONAL ASPECTS IN ULTRAENDURANCE ATHLETES

p0095 Adequate energy and fluid intake is needed to successfully compete in an ultraendurance race [108–116]. Most studies are descriptive in nature, reporting the distribution of carbohydrates, fats, and proteins the athletes ingested [5,9,10,16,17,19,108,111,112] (Table 14.4). As it can be seen in this table, the caloric intake of ultraendurance athletes relies mostly on carbohydrates followed by lipids and proteins. However, there are exceptions with relatively low carbohydrate intake which might be due to specific conditions such as cold environment. For instance, participants in an 800-km ultraendurance Antarctic race had caloric intake 23.7% from carbohydrates, 60.6% fats, and 15.7% proteins [59]. Some studies report the kind of food [113–115]. Also, some studies investigated the aspect of supplements [117–120].

s0045

Intake of Carbohydrates

p0100 Carbohydrates are the main source of energy intake in ultraendurance athletes [5,26,44,110]. When the intake of carbohydrates, fat, and protein was analyzed for ultraendurance athletes, the highest percentage was found for carbohydrates. Ultraendurance athletes consume ~68% of ingested energy as carbohydrates (Table 14.4). These athletes should consume more carbohydrates (90 g/h) than endurance athletes (60 g/h), and this recommendation should consider body mass and training status [121]. It has been shown that ultramarathoners might have an average carbohydrate intake of 31 g/h during race [122]. During the Marathon des Sables a carbohydrate intake of 42 g/h during race has been reported [123]. A male runner who covered 4254 km over 78 days had 56 g/h carbohydrate intake [124]. The carbohydrate intake of a female swimmer participating in seven open-water races of 15–88 km distance in 3–12 h duration was 83 g/h [125]. Not only the quantity but also the quality of the ingested carbohydrates is related to performance, e.g., an optimal glucose-to-fructose ratio during exercise might increase exogenous carbohydrate oxidation and contribute to manage gastrointestinal distress; however, an analysis of ultraendurance triathlon showed that athletes did not follow current recommendations on the glucose-to-fructose ratio [126].

s0050

Intake of Fat

p0105 An increased prerace fat intake leads to an increase in intramyocellular lipids in ultraendurance athletes [19]. Increased intramyocellular lipids might improve ultraendurance performance; however, there are no controlled

t0025 **TABLE 14.4** Intake of Energy in Ultraendurance Athletes in Different Disciplines

Distance and/or Time	Subjects	Intake of Carbohydrates (%)	Intake of Fat (%)	Intake of Protein (%)	References
CYCLISTS					
617 km in 24 h	1 male	64.2	27	8.8	[16]
2272 km in 5 d 7 h	1 male	75.4	14.6	10.0	[5]
4701 km in 9 d 16 h	1 male	75.2	16.2	8.6	[10]
RUNNERS					
100 km	7 males	88.6	6.7	4.7	[111]
501 km in 6 days	1 male	40.0	34.6	25.4	[9]
1005 km in 9 days	1 male	62	27	11	[114]
TRIATHLETES					
Deca Iron ultratriathlon	1 male	67.4	15.6	17.0	[112]
Gigathlon	1 male	72	14	13	[17]
Triple Iron ultratriathlon	1 male	72	20	8	[19]
Mean ± SD		68.5 ± 13.2	19.5 ± 8.5	11.8 ± 6.1	

SD, standard deviation.

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data in field studies whether fat loading improves ultraendurance performance. In a case report, ultraendurance performance in a rower was enhanced following a high-fat diet for 14 days [127]. An increased fat intake during an ultraendurance competition might improve performance. However, also for this aspect, no controlled data of field studies exist. In a case report on an ultramarathoner competing in a 6-day ultramarathon, the athlete consumed 34.6% of fat in his daily food intake [9]. Nonetheless, body fat decreased within the first 2 days and remained unchanged until the end of the race. In addition, performance slowed down after the first 2 days. Ultraendurance athletes consume ~19% of ingested energy as fat, which is higher than energy consumed in the form of protein (Table 14.4). A recent study reported that the intake of fat might vary by race duration with athletes participating in longer races presenting a higher percentage of energy derived by fat [122].

s0055 Intake of Protein

p0110 Regarding protein intake, athletes consume ~19% of ingested energy as protein during racing. An observational field study at the "Race Across America" showed that ultraendurance cyclists ingest rather large amounts of protein [113]. One might assume that athletes experienced a loss in skeletal muscle mass and try to prevent this loss by the use of amino acids. A recent study tried to investigate whether an increase in amino acids during an ultramarathon may prevent skeletal muscle damage [128]. However, the intake of amino acids showed no effect on parameters related to skeletal muscle damage. The protein intake of a female swimmer participating in seven open-water races of 15–88 km distance in 3–12 h duration was 12 g/h [125].

s0060 Intake of Ergogenic Supplements, Vitamins, and Minerals

p0115 Vitamin and mineral supplements are frequently used by competitive and recreational ultraendurance athletes during training [114,115,118,119] and competition [112–115]. In some studies the intake of ergogenic supplements, vitamins, and minerals by ultraendurance athletes and its effect on performance have been investigated [117,118,120]. In long-distance triathletes, more than 60% of the athletes reported using vitamin supplements, of which vitamin C (97.5%), vitamin E (78.3%), and multivitamins (52.2%) were the most commonly used supplements during training. Almost half (47.8%) the athletes who used supplements did so to prevent or reduce cold symptoms [120]. The regular intake of vitamins and minerals seems, however, not to enhance ultraendurance performance [117,118,129]. In the "Deutschlandlauf 2006" of over 1200 km within 17 consecutive stages, athletes with a regular intake of vitamin and mineral supplements in the 4 weeks before the race finished the competition no faster than athletes without an intake of vitamins and minerals [116]. In a Triple Iron ultratriathlon, athletes with a regular intake of vitamin and mineral supplements before the race were not faster [118]. Furthermore, the intake of chronic probiotic supplementation before and after the Marathon des Sables did not influence extracellular Hsp72 [129]. Also, ultraendurance cyclists who consumed antioxidant vitamins such as C and E did not show pronounced changes in their endogenous antioxidant defenses to exercise-induced reactive oxidative stress [130].

s0065 Fluid Intake During Endurance Performance

p0120 Ad libitum fluid intake seems to be the best strategy to prevent from EAH and to maintain plasma sodium concentration [41,75,86,131–134]. A rather low fluid intake between 300 and 400 mL/h seems to prevent EAH [41,98,115]. A mean ad libitum fluid intake of ~400 mL/h maintained serum sodium concentration in a 4-h march [131], and fluid consumption of ~400 mL/h prevents from EAH in a 161-km race in the cold [95].

s0070 Sodium Supplementation During Endurance Performance

p0125 One might argue that the supplementation with sodium during an endurance race might prevent from EAH. However, two studies on Ironman triathletes showed that ad libitum sodium supplementation was not necessary to preserve serum sodium concentrations in athletes competing for about 12 h in an Ironman triathlon [135,136].

s0075 CONCLUSIONS AND IMPLICATIONS FOR FUTURE RESEARCH

p0130 Regarding these findings we see that ultraendurance athletes face a decrease in body mass most probably due to a decrease in both fat mass and skeletal muscle mass. During racing, the athletes are not able to cover the energy deficit. Athletes with increasing length of an ultraendurance performance tend to have an increased fluid intake which seems

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to lead to both an increased risk for EAH and limb swelling. In summary, an energy deficit seems to be unavoidable in ultraendurance performances. Potential strategies might be to increase body mass by a prerace diet to fat mass and strength training to increase skeletal muscle mass. Another possibility could be to increase energy intake during racing by consuming a fat-rich diet. However, future studies are needed to investigate these aspects. Regarding fluid metabolism, the best strategy to prevent both EAH and limb swelling is to minimize fluid intake to ~300–400 mL/h.

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BAGCHI: 14

Non-Print Items

Abstract
In ultraendurance races, athletes face limits in nutrition regarding energy and fluid metabolism. An ultraendurance performance lasting for 24 h or longer leads to a mean daily energy deficit of ~7000 kcal. This energy deficit leads to a decrease in body mass, covered by a decrease in both fat mass and skeletal muscle mass. The energy deficit cannot be prevented by adequate energy intake. To avoid dehydration during an ultraendurance performance, adequate fluid intake is required. In case of fluid overload, both exercise-associated hyponatremia (EAH) and swelling of limbs may occur. Adequate ad libitum fluid intake of ~300–400 mL/h may prevent both EAH and swelling of limbs. To summarize, in ultraendurance races, an energy deficit seems to be unavoidable. Potential strategies might be to increase prerace body mass by a diet to increase fat mass and/or strength training to augment skeletal muscle mass. Another possibility could be increasing energy intake during racing by consuming a fat-rich diet. However, future studies are required to investigate these aspects.

Keywords: Energy deficit; Exercise-associated hyponatremia; Fluid overload; Limb swelling.